Impact of forage presentation on the equine brachiocephalicus mechanical nociceptive threshold (MNT) and forelimb kinematics

Aidan McAteer; Robin Gill; Roberta Ferro de Godoy

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Impact of forage presentation on the equine brachiocephalicus mechanical nociceptive threshold (MNT) and forelimb kinematics

Aidan McAteer[1]; Robin Gill[1]; Roberta Ferro de Godoy[1*]
[1]Writtle University College, Lordship Road, CM1 3RR, Chelmsford, United Kingdom

Roberta Ferro de Godoy (*corresponding author): roberta.godoy@writtle.ac.uk
Aidan McAteer: aidan.mcateer@writtle.ac.uk
Robin Gill: robin.gill@writtle.ac.uk

Abstract

Aims: The aims of this investigation was to specify whether haynet feeding or floor feeding causes different areas of sensitivity/tensions in the *m. brachiocephalicus*. The secondary aim additional was to elucidate whether specific areas of tension within the *m. brachiocephalicus* would affect the protraction and retraction of the forelimb.
Methodology: 10 horses (7 geldings; 3 mares) were used in the study with an age range of 614. Horses were split into 2 groups of their already established feeding methods (5 haynet feeders; 5 floor feeders). Each horse was assessed for points of sensitivity in the *m.brachiocephalicus* at its origin, insertion and muscle belly, by the use of a pressure algometer. The horse was then walked past a camera for kinematic analysis. Motion analysis software was used to measure the protraction and retraction of each forelimb. Shapiro-Wilk tests were used to measure normal distribution. Data that was deemed normally distributed was analysed using Independent T-Tests. Data that was not deemed normally distributed was analysed using Mann Whitney-U tests.
Results: The results of the study suggest that the use of haynet feeding has a negative impact on the muscular tensions of the *m. brachiocephalicus*, most significantly at its insertion. Additionally, haynet groups indicated increased levels of tension in both the muscle belly and origin. It was not significant the effect the points of tension seen throughout the *m. brachiocephalicus* have over the kinematics of the forelimb. It can be concluded that haynet feeding increases *m. brachiocephalicus* sensitivity/tension, which could possibly impact horse welfare and performance.

Key words: feeding practice, horse, muscle tension, pressure algometer

Background

A UK survey on the practice of feeding hay concluded that many people preferred to feed hay on the floor rather than a hay net (Brown and Powell-Smith, 1994). This was further supported by Townson *et al.* (1995), that reported that 57% of Irish racing stables chose the same method as Brown and Powell-Smith, (1994). Alternatively, in a more general survey given out to the UK population on choice of hay feeding method, 90.5% of the respondents preferred to feed from a haynet (Waltham, 1997). It is postulated by Harris (2010), that despite the more natural feeding posture floor feeding allows, the use of a haynet is preferred as it reduces the risk of wastage and contamination with faeces and urine. However, the use of the haynet has its own added disadvantages as it is suggested that it may adversely affect muscles and nerve function (Hintz 1997).

As of yet, only two studies have been able to definitively define the role that the *BC.m* has to play on forelimb protraction (Tokuriki *et al.,* 1999; Kienapfel, 2014). In a systematic review by McAteer (2019), the literature available on the topic of the *m.brachiocephalicus* showed a severe lack in knowledge surrounding the functionality of the muscle and its role in equine biomechanics. The topic is still largely at debate amongst many industry professionals. Any evidence that is readily accessible to the industry is severely lacking in evidence-based findings as many conclusions are ambiguous with anecdotal and circumstantial findings to back up observations and key points. Only a handful of sources have identified the *m.brachiocephalicus* as a muscle that plays a key role in the biomechanics of the forelimb (Payne *et al.,* 2006; Kienapfel, 2014) and more specifically the protraction phase (Tokuriki *et al.,* 1999). A more recent study further suggests that and m.*brachiocephalicus* muscle activities can be associated with stride frequency and speed of racing thoroughbreds when fatigued. Therefore, furthering the understanding of the effects deficits could place on the functionality of the muscle (Takahashi *et al.,* 2020).

Localised muscle soreness can lead to a varying amount of subtle performance problems such as reluctance to work on the bit/accepting contact and slight gait abnormalities. Furthermore, they are also known to have a shortening effect over the cranial phase of the stride ipsilateral to the afflicted muscle (Dyson, 2011). These observations, however, tend to be based on experience in the industry and would require quantifiable research in order to back up this statement. Scientific research is still severely lacking on this topic. The clinical significance of localised muscle tensions is rather poorly understood and badly documented which can be related to its subjective nature and lack of standardized procedure. Palpation is a keyway in determining the location and severity of musculoskeletal ailments, however this technique is highly subjective on the assessor (Varcoe-Cocks *et al*., 2006). Pressure algometry (PA) allows for the quantifiable results of musculoskeletal tenderness with many human studies providing its reliability and validity (Fischer 1987; Magora *et al*. 1991; Bendtsen *et al*. 1995; Brown *et al*. 2000). An investigation led by Kinser *et al*. (2009) studied the reliability and validity of PA by using Pearson correlations tests to compare force plate readings with maximum PA readings. The authors concluded that application was deemed relatively consistent, signifying that the device could lead to reliable and repeatable results. However, it is difficult to trust the conclusion of the investigation as a lack of presentation of results, increases the risk of author bias. In contrast to this, Varcoe-Cocks *et al*. (2006) aimed at investigating mechanical nociceptive thresholds (MNTs) using PA in order to correlate severity of clinical signs and subjective scoring of palpable muscle pain in horses with presumed sacroiliac dysfunctions. The study concluded that in cases of presumed sacroiliac dysfunctions horses displayed lower MNTs suggesting increased levels of pain supporting the role a PA has in providing non-subjective methods in producing quantifiable results for musculoskeletal pain.

In order to perform effective and efficient movements, it is imperative that the soft tissue is functioning properly. Impairment to the soft tissue structures within the musculoskeletal system will directly affect the quality and efficiency of any movement. Dysfunctional tissue is non-pathological meaning it is free from disease, inflammation and non-injured and instead refers to pain or tension within the structures (Wathen, 2002).

A preliminary investigation on the effects of head and neck position during feeding on the alignment of the cervical vertebrae in horses has shown that when housing practices such as feeding from haynets and hay bars are compared to floor feeding notable differences in muscle tensions along the neck were examined. More specifically, when horses fed from a haynet were compared with horses fed from the floor, more unilateral abnormalities were felt across the neck (Speaight *et al.,* 2016). In another investigation aimed at looking at BC.*m* tenderness found that asymmetrical muscle tenderness in BC.*m* may have an influence over forelimb kinematic, concluding that further research is recommended with a larger population and a defined trot speed to establish the full extent of its influence.

The aims of this investigation is to specify whether haynet feeding or floor feeding causes different areas of tensions in the *m. brachiocephalicus*. It is then the additional aim of this investigation to specify whether specific areas of tension within the *m. brachiocephalicus* correlate with differences in the protraction and retraction angles of the forelimb from points of tension found in the muscle.

Our hypothesis was that haynet feeding techniques have an effect over the tension in the *m. brachiocephalicus* when compared with floor feeding, which will then impact protraction/retraction of the forelimb.

Materials and methods

The investigation was an observational study as no intervention was included. Participants were measured with their regular feeding technique which they had been using for at least a year. The participants were split into two groups of their already established feeding methods, five haynet feeders and five floor feeders.

Ethics Approval

The data has been acquired according to modern ethical standards and has been approved by the Animal Welfare and Ethics Committee of Writtle University College. The approval number is 98360253/2019. A written informed consent was obtained from the owners of the participants of the study. Prior to the investigation, all horses were assessed for signs of lameness. Horses were introduced to any devices used throughout the trial and the environment in which the assessment was being held, to reduce anxiety and prevent injury.

Animals

Sample size in an investigation is key to the investigation's success. In order to ensure the correct sample size is chosen, a sample size calculation was carried out. This ensured that not too few participants were selected, reducing scientific validity and questioning reliability of results. Similarly, it additionally ensured that not too many participants were selected brining about false positive conclusions and breaching ethics. As the study at hand investigated tension within a muscle of a haynet feeder and a floor feeder, two independent groups were deemed necessary. As such the resource equation was used (Arifin and Zahriruddin, 2017) and a number of 5 horses per group; floor feeders and haynet feeders was defined. To ensure an accurate population representation 10 participants (7 geldings; 3 mares) were included in this study. Eight horses were still in ridden work whereas two had been retired due to the owners personal situation. 5 HF participants were in moderate work loads within a riding school where as only 3 FF participants were in the same level of work. Horses ages ranged between 6-14 years old, to gain a representative sample group of those having reached skeletal maturity. This age range was chosen specifically as it is noted by Bennett (1999) that growth plates within the vertebrae take 3.5-6 years to close, therefore, to ensure skeletal maturity, each participant had to be a minimum of 6 years old. It was noted by Fortin *et al*. (2014) that in older horses, age can influence the musculoskeletal functionality and as such the maximum age of participants was 14 years old. The participants were split into two groups of their already established feeding methods, which they had been using for at least a year; five haynet feeders (HF) age 9.8 ± 1.9 y/o and five floor feeders (FF) age 10.6 ± 1.6 y/o. Haynets utilsied were of all the same size holes (2inches) hung 1.5metres. All horses included are regular shoed and checked by a veterinary professional on a semestral basis. Each horse was assessed by a qualified Veterinary Physiotherapy practitioner.

Pressure Algometer

Pressure algometry (PA) allows for the quantifiable results of musculoskeletal tenderness with many human studies providing its reliability and validity (Fischer 1987; Magora *et al*. 1991; Bendtsen *et al*. 1995; Brown *et al*. 2000). Mechanical nociceptive threshold (MNT) of the *m. brachiocephalicus* were carried out using a pressure algometer (FDX 100 Algometer, Wagner Instruments) with a blunt 1cm^2 probe and results were noted in Newton (N). MNT were measured on three defined points of the *m. brachiocephalicus*. These points included the muscle origin and insertion and the muscle belly as similarly used in previous investigations (Purchas, 2015; Speaight et al., 2016) (Figure 1). Clavicular insertions were not used this investigation as there was a preference in assessing the muscle belly of the *m. brachiocephalicus* as a whole and not individual muscles as stated in Budras, (2009).

Figure 1: Points of measurement for the pressure algometer on the *m. brachiocephalicus.* Origin: distally to the deltoid tuberosity. Insertion: caudal to the wing of atlas. Muscle Belly: proximal to C5.

All algometric measurements were carried out by one investigator (AM), and the pressure threshold was measured. Values were then noted by an observer without the investigator (AM) seeing the values ensuring blinded therefore bias within pressure applied. Horses were restrained using their own head collar and lead rope appropriately fitted and held by an assistant before readings were taken bilaterally down the neck. The head of each horse was held in a neutral position above vertical by the assistant whilst the investigator (AM) took each measurement. The pressure algometer was placed perpendicular to each measuring point to measure the tension on three allocated points (Figure 2). At first, the pressure algometer was held in light contact with the skin for about 3 s, to reduce any reaction due to startle effects. Afterwards the pressure was gradually increased in 2 s–3 s intervals based on the studies of Haussler (2020) as well as Pongratz and Licka (2017). As a positive reaction indicative of reaching MNT behaviours (muscle twitch, head moving abruptly, nose flare, eye tensing) were noted, the pressure was stopped the the value noted. Each point was measured three times in order to ensure a consistency in measurement across horses, thus allowing for a more reliable method and valid results. The measurements began at the origin, then the muscle belly and finally the insertion, first the right *m. brachiocephalicus* then the left one.

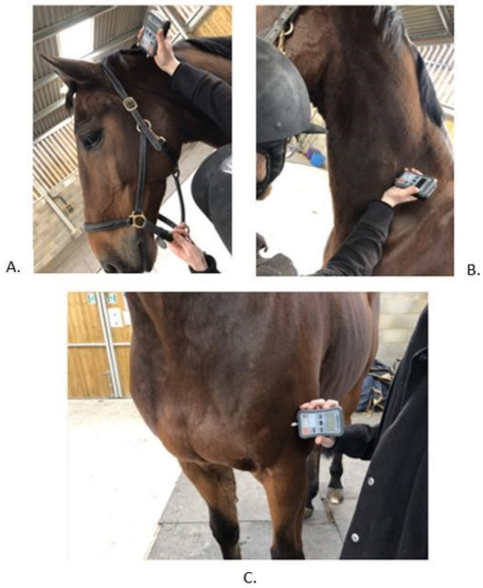

Figure 2: Images taken throughout trial, indicating pressure algometer measurement points p. (A) insertion of *m. brachiocephalicus*: caudal to the wing of atlas; (B) belly of *m. brachiocephalicus:* proximal to C5; (C) origin of *m. brachiocephalicus*: distally to the deltoid tuberosity.

Video collection

Reflective markers were positioned on the horses forelimbs to allow a precise measurement of protraction and retraction angles. The markers were placed on each horse's scapula spinae tuber and coronary band by the same researcher (AM). Videos for forelimb kinematics analysis were recorded at 240fps (iPhone 8 , Apple). The camera was place on a tripod, 5 m away from the walking area (Figure 3). Horses were videoed at walk six times, three videos recording the left side and three videos recording the right side. All subjects were walked at their comfortable speed and efforts to maintain their pace were made by the handler, so as to ensure full assessment of the influence the *m. brachiocephalicus* had over the limb. The surface used was a soft rubber matting to ensure no slipping on concrete flooring effecting results of the angles of protraction and retraction or injuring the individual.

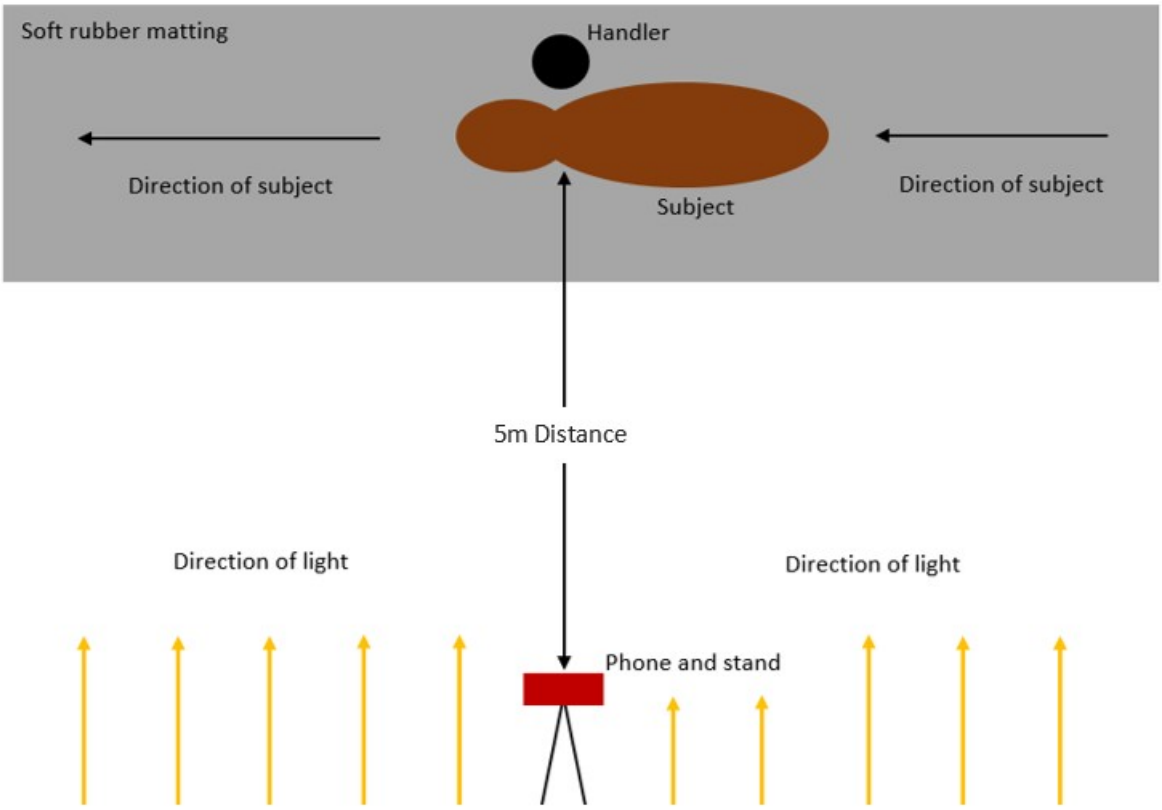

Figure 3: Layout of the videoing for Kinematic Analysis

Kinematics Analysis

A motion analysis software (Quintic Biomechanics v31, Quintic Consultancy, Birmingham, UK) was used to analyse the protraction and retraction of each horse from the videos recorded. Budras et al. (2009) evidenced the role the *m. brachiocephalicus* plays in protraction of the forelimb, as such, any restriction in the muscle may have an overall effect on the limbs ability to efficiently complete a cycle.

Protraction and retraction angles were measured against the vertical line (Figure 4). Limb protraction and retraction angles were defined by the angle formed by the limb's axis relative to the vertical during the stride. The limb's axis was defined for the entire limb from the segment formed by the Two markers placed, spine of scapula and coronary band.

Figure 4: Protraction and retraction angles measured against the vertical

Statistical Analysis

Intra-operator reliability was assessed using intra-class correlation coefficient (ICC). ICC was determined for the assessor on all anatomic landmarks and all horses The data obtained from each point (3 algometer readings) and each protraction and retraction angle (3 videos) were averaged. The data was analysed statistically with SPSS (v.26, IBM *SPSS* Statistics for Windows. Armonk, NY). Continuous variables with normal distribution were presented as mean±standard deviation; non-normal variables were reported as median (interquartile range [IQR]). Shapiro-Wilk test was used to assess data for normality. Data that was deemed to be of normal distribution by the analysis of the Shapiro-Wilk normality test was analysed using independent t-test to compare the two independent groups. On other hand, non-parametric data was analysed using Mann-Whitney U test. The significance level was set at 95% ($p<0.05$).

Results

Pressure Algometer Scores

The ICC coefficient for the single assessor, considering all points measured, was 0.066 ($p < .001$).

Data of 5 haynet feeding (HF) and 5 floor feeding (FF) participants were analysed. The differences in MNT between FF and HF at the origin of the *m. brachiocephalicus* were found to be statistically significant in both sides. Data included is mean ± standard deviation, unless otherwise stated. At the left side, the FF group ($19.28 \pm 3.48 N/cm^2$) had a mean difference of $6.50 N/cm^2$ more MNT in relation to the HF group ($12.78 \pm 2.67 N/cm^2$), $t(8) = -3.103$, $p = 0.015$ (Figure 5a). Likewise, the right side has shown a significant increased MNT on the FF animals

(18.00 ± 4.44N/cm^2) in relation to horses having forage presented on a haynet (12.26 ± 1.47 N/cm^2) ($t(8) = 3.103$, $p = 0.015$) (Figure 5b).

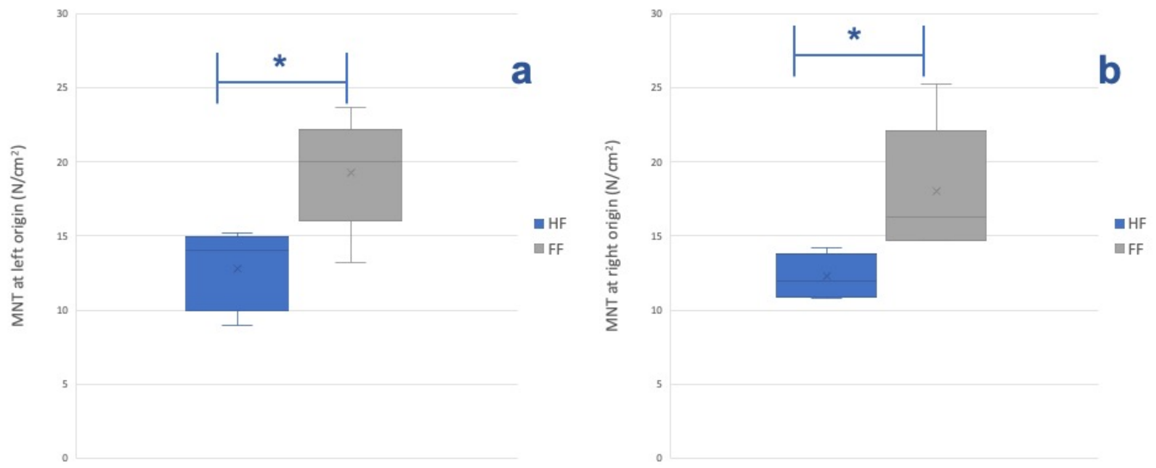

Figure 5: Mechanical nociceptor threshold (MNT) at the at the origin of the *m. brachiocephalicus* for horses that are floor feeders (FF) (n=5) and haynet feeders (HF) (n=5). The bottom and top of the box are the first and third quartiles, the band inside the box is the second quartile (the median), and the 'x' is the mean. The lines extending vertically from the boxes (whiskers) indicate the minimum and maximum of all of the data. * represents significant differences between HF and FF groups (p<0.05).

At the muscle belly, there was a significant increase in MNT for floor feeders (FF) (13.48 ± 0.63N/cm^2) in relation to haynet feeders (HF) (8.70 ± 2.69 N/cm^2) on the left brachiocephalicus ($t(8) = -4.156$, $p = 0.003$) with difference of 4.78 N/cm^2 between feeding practices (Figure 6a). Likewise, on the right side there was a significant higher MNT on the FF group (Median= 14.20 (3.4) N/cm^2) when compared with HF group (Median=8.9 (2.0) N/cm^2) at the muscle belly level (U = 25.00, $p = 0.008$) with an overall difference of 3.40N/cm^2 (Figure 6b).

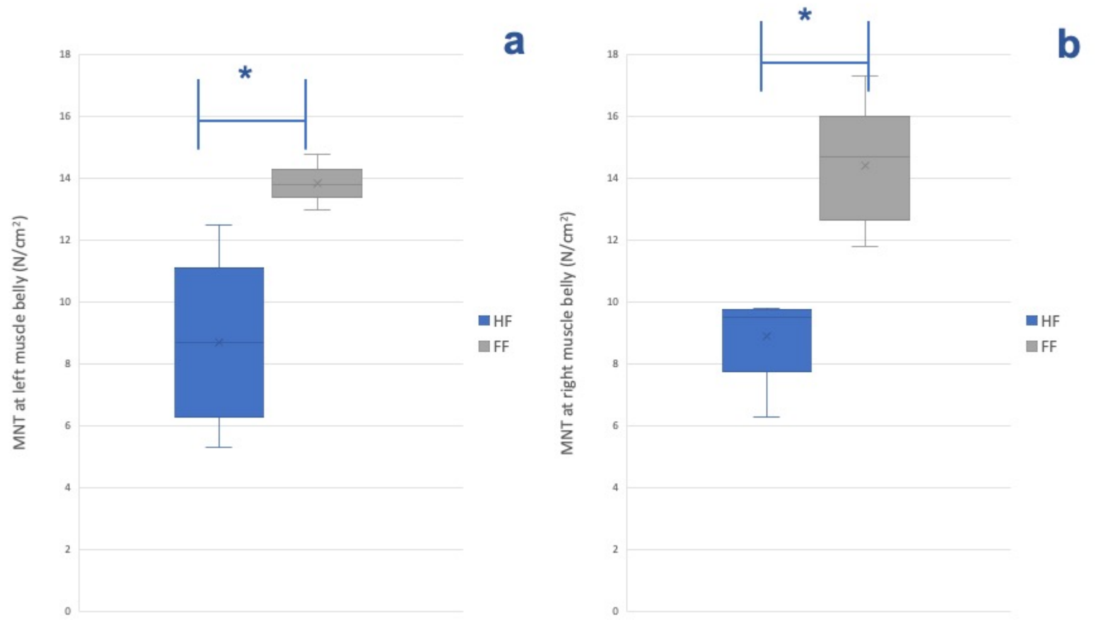

Figure 6: Mechanical nociceptor threshold (MNT) at the at the belly of the *m. brachiocephalicus* for horses that are floor feeders (FF) (n=5) and haynet feeders (HF) (n=5). The bottom and top of the box are the first and third quartiles, the band inside the box is the second quartile (the median), and the 'x' is the mean. The lines extending vertically from the boxes (whiskers) indicate the minimum and maximum of all of the data. * represents significant differences between HF and FF groups ($p<0.05$).

Likewise, the insertion of the *m. brachiocephalicus* has shown significant differences between FF and HF. At the right brachiocephalicus, the HF MNT (7.68 ± 1.30N/cm^2) was statistically significant lower then the FF MNT (13.08 ± 1.12 N/cm^2), with a mean difference of 5.40N/cm^2 between groups ($t(8)$ = -7.008, p = 0.000112) (Figure 7b). On the left side, the trend was similar, with horses being fed forage at the floor showing higher MNT (Median=11.20 (3.6) N/cm^2) than the horses feeding from haynets (Median=7.8 (2.9) N/cm^2) (U = 25, p = 0.008) (Figure 7a).

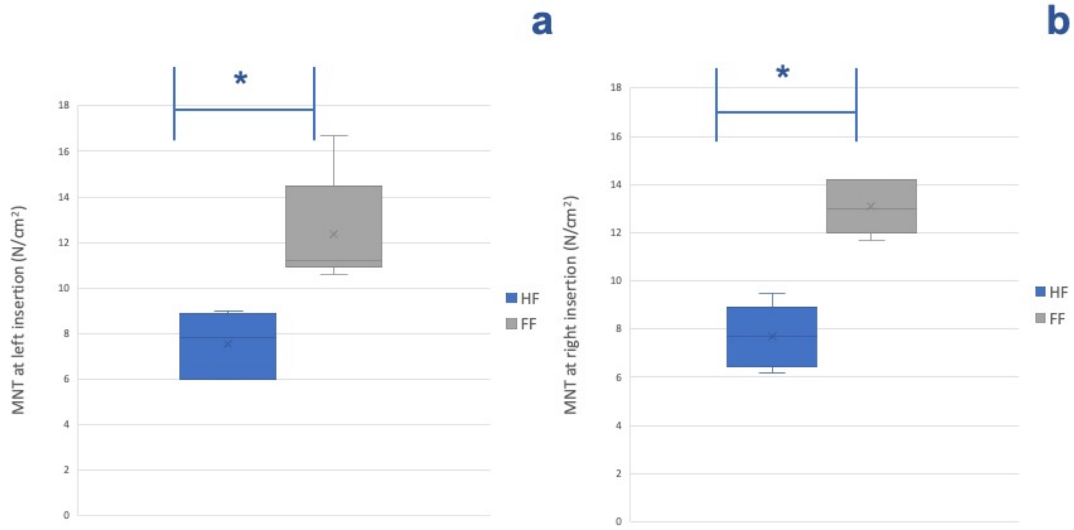

Figure 7: Mechanical nociceptor threshold (MNT) at the at the insertion of the *m. brachiocephalicus* for horses that are floor feeders (FF) (n=5) and haynet feeders (HF) (n=5). The bottom and top of the box are the first and third quartiles, the band inside the box is the second quartile (the median), and the 'x' is the mean. The lines extending vertically from the boxes (whiskers) indicate the minimum and maximum of all of the data. * represents significant differences between HF and FF groups (p<0.05).

Forelimb Kinematics

Forelimb protraction was not statistically significant different between FF and HF for the left ($t(8) = -0.048$, $p = 0.963$) and right ($t(8) = 0.866$, $p = 0.412$) forelimbs. Retraction was also not statistically significantly different between groups on the left ($t(8) = 0.156$, $p = 0.880$) and right ($t(8) = 0.213$, $p = 0.836$) forelimbs. Table 1 shows mean±SD for protraction and retraction angles.

Table 1. Mean±SD of right and left forelimbs protraction and retraction angles (°) for horses that are floor feeders (FF) (n=5) and haynet feeders (HF) (n=5).

		Floor feeders (n=5)	Haynet feeders (n=5)
Protraction (°)	Left forelimb	20.19±3.14	20.11±1.58
	Right forelimb	19.32±2.07	20.59±2.55
Retraction (°)	Left forelimb	15.24±2.56	15.02±1.78
	Right forelimb	14.70±3.05	15.05±2.11

Discussion

The purpose of this investigation was to specify whether haynet feeding or floor feeding caused different areas of tensions within the *BC.m* and whether these changes had an effect over the disputed role the *BC.m* plays on kinematic of the forelimbs of the horse. The study was carried out following a systematic review by McAteer, (2019), which concluded that the effects of extrinsic factors on the *m. brachiocephalicus* is still largely misunderstood within the industry as evidence available is largely anecdotal and unreliable. The purpose of this investigation was to specify whether haynet feeding or floor feeding caused different areas of sensitivity within the *m. brachiocephalicus* and whether these changes had an effect over the role the *m. brachiocephalicus* on kinematic of the forelimbs of the horse.

Our hypothesis that forage feeding practice would affect *m. brachiocephalicus* sensitivity was confirmed in this study, with horses feeding forage from haynets showing a significant increase in muscle sensitivity. However, unexpectedly we have seen that this increased sensitivity did not affect the forelimb movement in terms of protraction and retraction at walk.

In summation, the results of this study show that whilst tension may be more significant in the *m. brachiocephalicus* for haynet feeders when compared to the floor feeder, this tension does not show a significant effect over the kinematics of its associated limb. Therefore, it is possible to suggest that domestication practice of haynet feeding is more likely to negatively impact musculature such as the *m. brachiocephalicus*. However, it is not currently possible within this investigation to define the *m. brachiocephalicus* as a muscle that may affect forelimb kinematics as previous studies have indicated (Tokuriki *et al*., 2010; Purchas, 2015; Takahashi *et al.,* 2020).

The findings indicate that the use of a haynet feeding method is a potential cause for increased tension of the *m. brachiocephalicus.* Similar findings have only been observed in one other study. Speaight *et al*., (2016), preliminary study indicated that there was increased *m. brachiocephalicus* tension in horses that fed from both haynet and haybar feeding methods when compared to the floor feeding participants. It is difficult to draw comparisons with the current study as points of tension measured were vague (poll, neck and shoulder) and lacked presentation of data. Regardless, there is evidence to suggest that feeding methods may affect neck muscles tension in both the current study and Speaight's investigation.

Significant decreases in MNT were noted among haynet feeders in comparison to floor feeders on both sides of the neck and in all three points studied. This demonstrated that in HF the muscle presented with a lower sensitivity threshold, signifying more sensitivity. Across both the groups, it was noted that insertion of the muscle (wing of atlas) accounted for the highest levels of sensitivity. Raw data demonstrated, the pressure algometer scores at the insertion for haynet feeders ranged from 6.0N to 9.5N whereas, for floor feeders ranged from 10.7N to 16.7N indicative of the possible effects feeding methods may have on this specific point. It has been expressed that underlying tissue thickness are important factors in the production of MNTs, where significant differences in spinal MNT values have been reported for landmarks over muscle and bone (Haussler, 2020), which is why within the study it was expressly noted that all points were measured away from bony landmarks and nerve bundles to eliminate such discrepancies. It can be suggested that a primary reason for increased tension at the wing of atlas (insertion) is due to the anatomical structure and function of the atlantooccipital and atlantoaxial joints. Together, they allow the horse to move its head up and down as well as side to side in order to facilitate daily functions such as grazing or feeding from a haynet (Pilliner *et al*., 2013). Furthermore, Hodgson *et al.,* (2022), investigated the forces required to feed from a haynet concluding that haynets hung lower required greater force to feed than haynets hung higher. As such the increased torque required to pull hay from the haynet may explain the increased sensitivity in this area. It is important to note that the results of this investigation mirror that at hand suggesting the point at the wing of atlas has an increased sensitivity in comparison to all other points due to anatomical function.

In general, it was likewise noted that at the muscle belly, haynet feeders showed an overall increased sensitivity. In the context of feeding, it may be suggested that increased sensitivity of muscle belly of the haynet group when compared to the floor feeding group may be caused by either a favored side or positioning of the haynet. Floor-Feeders on the other hand, do not have this issue when it comes to feeding as the head and neck remains straighter and requires less force to obtain hay as evidenced by the two non-working floor-feeders.

The findings of the statistical analysis concluded that an increased sensitivity of the *m.brachiocephalicus* does not have an effect over kinematics of the forelimb. Kinematic data within this study noted no significant differences between protraction and retraction angles between groups. However, limited research exists that collectively defines the role that the *m.brachiocephalicus* plays in forelimb kinematics. From an investigation by Tokuriki *et al.,* (2010) it can be assumed that the *BC.m* is categorised as a forelimb muscle and not a cervical muscle as electromyography readings evidenced that muscle activity of the *m.brachiocephalicus* during the limb protraction phase of locomotion was highest aiding in the protraction of that limb through water than on land. Previous studies Kienapfel, (2014) and Purchas (2015); inferred that tensions within the *m. brachiocephalicus* had an effect over the kinematics of the forelimb. However, this was resultant of a hyperflexed head and neck position causing an anteversion of the forelimb or horses being ridden on the contact, making it difficult to compare results to the investigation at hand. This shows that the evidence that is available to the scientific and veterinary industry can only be assumed by gathering conclusions from other studies inclusive of the current investigation.

The main limitations within this investigation, was the small participant yield used for each group as well as the range of levels of work each horse was in. Therefore, the study, as a whole, may not have been representative of the equine population when compared to a larger participant yield as well as other extraneous variables. The conclusions drawn from this study may be difficult to generalize to the wider equine population. A limitation in terms of the kinematic data may have been introduced by the lack of control over walking speeds of each subject within the trial. The aim of the investigation was to analyse the horse walking at its standard speed in order to evaluate the effect the *BC.m* had over natural gait without the interference of speed control from the handler or rider. Where this was optimal to evaluate the full effect that the *BC.m* had over forelimb kinematics, a lack of standardistaion of the horses natural speed resulted in a variety of speed produced by each horse meaning that a true correlation between subjects is difficult to determine at this time. Nevertheless, a standarised speed would not have been appropriate as the selection of participants in the investigation ranged from 12hh ponies to 17hh horses, therefore, a speed suitable for one may not be suitable for another. The lack of speed calculations completed within the kinematic analysis of each subject meant that mean speed of each subject could not be measured. As a result of lack of speed control there may be an unforeseen effect over the stride length, therefore, the lack of speed calculations increases the risk of anomalous results that may affect conclusions derived from the investigation at hand.

The evidence of the effects of domestication practices, such as feeding methods, on the equine species can be summarised by culminating research that is collectively available, however what is available to the industry is often conflicting and lacking in accuracy. As such, the investigation at hand begins to evidence the effects such practices have on the muscles of the equine neck, setting out a foundation for further investigations to take place. From data accrued throughout this investigation, it was possible to support that haynet feeders are more prone to increased sensitivity throughout the *m. brachiocephalicus* as a collective muscle. The insertion of the *m. brachiocephalicus* is the most susceptible to these changes in tension. This may be due to the role played by the atlantoaxial and atlantooccipital joints which aid feeding behaviour. The conclusions derived from the muscle origin and belly however, cannot be clinically reasoned due to a number of extraneous variables not eliminated due to a lack of additional parameters not included. The effect the tension in *m. brachiocephalicus* had over kinematics of the forelimb could not be accurately determined. It is therefore not currently possible to deduce the effect feeding methods have over the kinematics of the forelimb. This study does however add to the understanding of the effects human domestication has had on the body of the equine. It therefore can set out an understanding of how to better manage the horse within both companion and competitive environments.

Declarations

***Funding**

This research has not received any funding.

Conflicts of Interest

The authors declare that there are no conflicts of interest

Ethical Approval

The material in this manuscript has been acquired according to guidelines set by The Animal (Scientific

Procedures) Act 1986 and the Declaration of Helsinki and has been approved by the Animal Welfare and Ethics Committee of Writtle University College. The approval number is 98360253/2019. A written informed consent was obtained from the owners of the participants of the study.

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Data Availability

The data that support the findings of this study are available from the corresponding author, RFG, upon reasonable request.

Authors' Contributions

AM- data collection, data analysis, conceptualisation, paper writing

RG- supervision, conceptualisation, paper review

RFG- conceptualisation, data analysis, paper review

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